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Optimizing the Army's base realignment and closure implementation while transforming and at war

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THESIS

OPTIMIZING THE ARMY'S BASE REALIGNMENT AND CLOSURE IMPLEMENTATION WHILE TRANSFORMING AND AT WAR

by

Jeffrey B. House

June 2005

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OPTIMIZING THE ARMY'S BASE REALIGNMENT AND CLOSURE IMPLEMENTATION WHILE TRANSFORMING AND AT WAR

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

ACP	Army Campaign Plan
BRAC	Base Realignment and Closure
BRACAS	Base Realignment and Closure Action Scheduler
COBRA	Cost of Base Realignment Actions
CONUS	Continental United States
DA	Department of the Army
DoD	Department of Defense
FY	Fiscal Year
GAMS	General Algebraic Modeling System
GAO	Government Accountability Office
GWOT	Global War on Terror
IGPBS	Integrated Global Presence and Basing Strategy
IMA	Installation Management Agency
LCM	Life Cycle Manning
MILCON	Military Construction
NPV	Net Present Value
RC	Reserve Component
TABS	The Army Basing Study

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She has also done a wonderful job of keeping me connected to the real and practical in my own life and my family's. She managed to do this while always encouraging me to do my best with the theoretical at school. Thanks, Beth. I couldn't have accomplished what I have without you.

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EXECUTIVE SUMMARY

The United States Army is transforming and at war. This transformation is enabled by the 2005 round of Base Realignment and Closure (BRAC). If approved, this BRAC round will require the Army to spend about $13 billion over six years, moving over 2,500 distinct units and undertaking military construction projects at about 180 locations. An anticipated savings of $24 billion over 20 years motivates this expense. During implementation of the last BRAC round in 1995, the Army used an integer linear program, the BRAC Action Scheduler (BRACAS), to prescribe BRAC implementation schedules. We modify BRACAS by adding unit-level resolution, including schedules and personnel strength to account for wartime deployments and transformation initiatives.

We conduct an analysis using data from a candidate set of recommendations that is very similar to the Army's final BRAC 2005 recommendations. We use this data to explore several scenarios. We manipulate both the input data and BRACAS constraints to consider anticipated BRAC implementation issues. These include the feasibility of BRAC implementation subject to unit availability, impact of implementation budgets on savings, budget requirements for accelerated or delayed implementation, regional Military Construction (MILCON) budget limits, and the impact of moving units on specified schedules before MILCON is complete.

We conclude the Army can execute BRAC with little disruption to transformation and deployment plans while still achieving projected savings. Our results indicate that total BRAC savings are not impacted by including the deployment and transformation schedule limitations of major units that will move during the implementation period. We find a need for at least a $500 million MILCON limit per region per year. Our results suggest unrestricted annual budgets would allow additional savings approaching $900 million. This invites a more detailed budget analysis to seek greater savings by making acceptable changes to planned annual BRAC budgets. Returning forces from Germany early can save additional money - up to $4 billion minus the additional facilities costs.

The improved BRACAS produces realistic execution plans, and generates a schedule of feasibly timed unit moves. The Army and the other services can use BRACAS to develop implementation plans and budgets that maximize savings while explicitly considering unit availability, the Integrated Global Presence and Basing Strategy, modularity requirements, and transformation.

I. INTRODUCTION

A. PURPOSE

We address the immediate need of the U. S. Army to plan to implement the 2005 Base Realignment and Closure (BRAC) recommendations. We seek a six-year implementation schedule that minimizes disruption to other transformation initiatives, supports wartime requirements for unit operational availability, and makes the best use of resources by generating the greatest savings within budget limits.

B. APPROACH

We use the Base Realignment and Closure Action Scheduler (BRACAS), a proven capital budgeting model used by the Army in past rounds of base closures [Dell, 1998]. We improve the model by incorporating unit-level fidelity. We introduce additional data regarding a unit's strength, and availability to move. These considerations allow some costs to be linked directly to feasible unit moves. We allocate costs according to unit strength, resulting in a more realistic budget proposal. We use the modified model to explore anticipated questions from senior decision makers and BRAC implementation planners.

C. OVERVIEW

We first present some BRAC background information. We highlight significant changes in the implementation environment since the previous BRAC round in 1995. We then present the modified BRACAS model. We use the model to explore questions we anticipate may arise in planning for BRAC implementation. We present results based on data that closely resemble the Army's list of recommended closures and realignments. We offer a few insights regarding scheduling of unit moves, budgeting, and management of military construction. Finally, we suggest further improvements to BRACAS.

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II. BACKGROUND

A. A BRIEF HISTORY OF BASE CLOSURES

1. Base Realignment and Closure

a. Why We Close Bases

Base realignments and closures are necessary to help the Department of Defense (DoD) adapt to changes in the world. As technology, strategy, and even demographics evolve, new missions are created, and old missions become obsolete. Organizations must occasionally rearrange their internal structure, reassign responsibilities and functions to different divisions, acquire new capabilities, and divest themselves of unneeded or unwanted capabilities [Garamone, 2005]. In this sense, DoD is no different than any large, diverse organization: it must continuously reassess its capabilities and adapt to remain relevant, efficient and ready.

b. Why We Legislate Base Closures

Unlike a normal business, Congress funds DoD. Two senators and one member of the House of Representatives can claim each installation in the United States. These installations provide jobs, and are important to the local economy. When a government proposal threatens the local economy in an elected official's district, he or she naturally is inclined to oppose it. This makes it difficult for DoD to close a facility, or even reorganize operations on a large scale without Congressional resistance.

Congress recognizes the legitimate need of DoD to close bases and realign missions in order to reduce the size of the defense budget and remain efficient. Past experiences have helped Congress develop and improve a process that insulates base closure decisions from political influence, and protects implementation actions from political derailment [Government Accountability Office (GAO), 1997].

Title XXIX of Public Law 101-510, as amended, dictates the process for BRAC [GAO, 2002]. In brief, the process begins with Congress authorizing a new round of base closures. The Defense Department conducts a study to determine which facilities are to be closed, based on specific criteria [DoD, 2005a]. The President appoints the Defense Base Closure and Realignment Commission to perform the oversight role normally provided by Congress. DoD submits its recommendations. The commission

reviews and studies the recommendations, and has the ability to add and remove recommendations. The commission's recommendations (not DoD's) are forwarded to the President, who must accept or reject the list as a whole. If he accepts the recommendations, Congress has a specified time frame to take positive action to end the process. If Congress does not act, the committee's recommendations become law. DoD must complete all closure and realignment actions within six years [DoD, 2005b]. Table 1 summarizes the timeline of key events.

Time Frame	Key BRAC Action
December 2001	Congress authorizes BRAC 2005
2003 through 2005	DoD conducts internal analyses
March 15, 2005	President appoints Base Closure and Realignment Commission
May 13, 2005	DoD announces recommendations
September 8, 2005	Commission recommendations due to President
September 23, 2005	President accepts or rejects Commission's list
October 20, 2005	Commission's revised list due to President if applicable

Congress has 45 legislative days from presidential approval to halt BRAC 2005
DoD has six years from presidential approval to implement recommendations

Table 1. BRAC 2005 Timeline (after DoD, 2005b).

2. The Role of BRACAS

BRACAS has been used during the development of the Army's 2005 BRAC recommendations to consider the total savings possible for proposed base closure scenarios given various budget options. In this role, BRACAS has served as a tool for senior decision makers to understand the fiscal implications of different options under consideration.

DoD released its recommendations on May 13, 2005 [DoD, 2005c]. As the review of the list progresses, the Army must develop a specific plan to implement the proposed recommendations. It must be prepared to adjust rapidly if recommendations are changed. There are many factors – some of them new – that must be incorporated into this planning effort. Several are described below. BRACAS accounts for these factors to help the Army develop an implementation plan now that will be ready to execute when BRAC recommendations become law.

B. THE CHANGED IMPLEMENTATION ENVIRONMENT

Four previous rounds of base closures took place in 1988, 1991, 1993 and 1995 [GAO, 2002]. During this period, DoD conducted a major reduction in the number of people on active duty, while the Army also reduced its structure from 18 to 10 active duty divisions. U.S. military forces were not heavily engaged in operations around the globe. The strategic situation changed radically in the wake of the collapse of the Soviet Union. In previous rounds, BRAC seemed like a natural part of the main focus of DoD – downsizing the force. Today the environment for implementing BRAC has changed dramatically.

1. The Operational Environment

Unlike past BRAC rounds, the present round finds the Army at war. Over 150,000 Soldiers are currently conducting combat operations in Iraq and Afghanistan [Dickson, 2005]. While we cannot know what the required force level will be over the six-year implementation period, it is prudent to assume that the current level of commitment will continue. Units are deployed for one-year tours, and some units have their deployments extended. All units require time to train before and recover after a deployment. This wartime reality restricts unit availability to move and is a critical factor in developing any BRAC implementation plan.

2. Transformation

The Army is undergoing a major restructuring of its operational forces. The Army Campaign Plan (ACP) is the roadmap for this transformation, and designates a time for each unit to adopt the new modular force structure. This modularity conversion takes a unit's full attention, and renders the unit unavailable for both deployment and relocation. Any acceptable implementation plan must support the ACP unit transformation timeline. [Department of the Army (DA), 2004a]

3. Life Cycle Manning

The Army has also scheduled units for implementing Life Cycle Manning (LCM) [DA, 2005]. Under LCM, most soldiers will arrive nearly simultaneously at a unit and will remain with the unit throughout its life cycle, typically three years. At the end of the life cycle, some soldiers may remain with the unit for the next life cycle, while others depart for different assignments and a fresh group of Soldiers replaces them. At the

beginning of a cycle, the unit is fully engaged in receiving new personnel and getting organized, and is unavailable for operational deployments [DA 2004b, 2005]. Shortly after the beginning of a unit's life cycle – when the majority of the personnel and their families have just arrived at the installation – seems the least appropriate time to move the unit. The rhythm of LCM must be considered in planning unit moves.

4. Reserve Component (RC) Forces

Since the beginning of the Global War on Terror (GWOT), RC forces have experienced a dramatic increase in activations and deployments, including extensive deployments to conduct combat operations. In this environment of increased operational demands on the RC, we are for the first time making considerable changes in RC installations as part of BRAC. The majority of the Army 2005 closure recommendations involve consolidation of multiple RC facilities into one nearby Armed Forces Reserve Center.

5. Return of Forces from Overseas

The IGPBS is under review and decisions are pending, but the intent to return large numbers of forces from Germany and South Korea to the United States has already been announced [Naylor, 2005]. These basing decisions are technically separate from BRAC, which only addresses closure or realignment of installations within the United States. Nevertheless, the Army recognizes the need to synchronize these two programs to close bases and move units. BRAC considers only the infrastructure needed to host forces returning from overseas, and does not consider the decision to move those forces. The Army will address both considerations with a viable plan for BRAC implementation that synchronizes all moves, regardless of where units are stationed.

6. Recruiting, Retention, and Stability

The Army is currently experiencing increased difficulty in recruiting [Hess, 2005]. Many factors may be contributing to the Army's difficulty in recruiting the desired number of soldiers. The GWOT may be deterring some recruits, and a positive economic picture may be contributing as well. Soldiers currently serving are staying in the Army at high rates, but the increased frequency, length, and danger of deployments have senior leaders very concerned about the long-term ability of the Army to retain experienced soldiers.

LCM and the transformation outlined in the ACP (including the creation of additional units to share in the deployment rotation) are key elements in retention. These initiatives aim to relieve some of the pressure on deployment frequency and length as well as provide families with a more stable home life while soldiers are deployed. Other personnel initiatives, such as allowing repetitive tours at the same installation, are designed to provide additional stability.

The key component in stability is predictability. The Army Force Generation Model, along with LCM, is designed to let both units and Army leaders know when a unit is available for operation [DA, 2004b]. It also affords Soldiers and their families some measure of predictability. It is important that BRAC implementation, to the extent possible, does not disrupt these initiatives. Disruption delays achievement of important Army goals and impacts the stability and predictability for Army families. One ACP objective is improving stability for soldiers and families, which emphasizes the need for planning BRAC implementation to "run in the background" as other initiatives move forward. [DA, 2004a]

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III. OPTIMIZING BRAC IMPLEMENTATION

A. HISTORY OF THE BRAC ACTION SCHEDULER (BRACAS) MODEL

1. The Purpose of BRACAS

BRACAS is a capital planning model. It was first developed after BRAC 1993 as an improved method of analyzing the trade-off between capital investment and future savings as the Army prepared for BRAC 1995. BRACAS can explore a variety of factors, including annual categorical expenditures, budget plan feasibility, optimal budgets for maximum savings, the timeline for completed actions, and a cost-benefit for accelerating military construction (MILCON). Policies under consideration can be modeled as additional restrictions, allowing a comparative quantitative analysis that supports decision makers.

2. History of BRACAS

Original versions of BRACAS were reported by Free [1994] and Wong [1995]. After some improvements and modifications, it was used by the Army in 1995 [Dell 1998]. AlRomaihi [2004] added environmental costs and considered their impact on implementation budgets. Subsequently, Dell and Royset implemented unpublished modifications in 2004 and 2005, including a stochastic version to model variability in environmental cleanup costs.

During BRAC 1995, the Army had already submitted its budget program before BRAC decisions were final. Afterwards, an analysis of potential savings was completed using BRACAS. The study showed the Army could realize an additional $233 million in net savings by spending $100 million earlier than originally projected. Army leaders reprogrammed funds within the budget to achieve this savings. We note here that the GAO [2005] has recently published their findings that cost and savings projections from prior BRAC rounds have been surprisingly accurate, and savings may be ahead of projections. In this sense, BRACAS may already have over $200 million in savings to its credit.

3. Strengths and Shortcomings

BRACAS has several strengths: It has a proven track record. It is known by the decision makers who set policies regarding BRAC implementation. It models all categories of costs that are calculated by the Cost Of Base Realignment Actions (COBRA) model, the approved tool for BRAC cost estimation [DoD, 2005d]. It may have helped the Army save several hundred million dollars already.

There are areas that need improvement. The Army must carry out the 2005 BRAC decisions in a far more complicated and constrained environment. BRAC implementation must be carefully planned and executed to prevent any disruption in combat operations. Prior versions of BRACAS did not model wartime considerations. Explicitly modeling these considerations at the beginning of the planning cycle ensures the Army begins with reasonable budget expectations and a feasible unit movement schedule.

The concerns above may seem exaggerated, but they must be considered. There is a theorem in optimization that guarantees one can never find a better solution to an optimization problem by adding a new constraint or restriction. Either the restriction will not have any effect, or it will make the situation worse by making a previous solution unattainable. The restriction of allowing units to move only during certain narrow windows of opportunity rather than at any time could, theoretically, be so limiting that no solution can be found at any cost. We do not anticipate anything so dire. However, if this arises, the only way to find a solution is to eliminate some other restriction – e.g., change the budget, the deployment schedules, and so on.

If the budget plans for BRAC produced by the current version of BRACAS do not allow a feasible solution while leaving other initiatives unchanged, the Army must either increase the required budget, reduce anticipated savings, or both. The savings in the early years of implementation help fund future years, so unrealized savings are a concern.

A more fundamental concern is the impact of unit moves on the Army’s ability to execute contingency plans. It is essential that operational planners know when forces are available, arguably much more essential than predicting budget requirements within tight

tolerances. Regardless of whether a unit is committed due to transformation, combat, or a BRAC-induced move, the unit is not available for other tasks.

Ensuring that the proposed implementation budget is created along with a feasible implementation schedule can help avoid potentially serious pitfalls. By exploring these issues simultaneously, we can be confident that we have found at least one way to successfully navigate the road ahead.

B. BRACAS FORMULATION

1. Indices

t, t' years of the closure process (t= 1, 2, ... , 20).

q, q' first/second half of the year (q= 1, 2).

l installation losing activity.

g installation gaining activity.

c construction type ($c \in \{$'normal', 'accelerated', 'slow'$\}$).

u units (or activities) moving from one installation to another.

r region ($r \in \{$'Northeast', 'Southeast', 'Southwest', 'Northwest', 'Pacific'$\}$).

2. Indexed Sets

G_l installations gaining unit from losing installation l.

G_r installations gaining unit located in region r.

L_g installations losing unit to gaining installation g.

U_l units moving from losing installation l.

U_g units moving to gaining installation g.

U_{lg} units moving from losing installation l to gaining installation g.

3. Data

a. Losing Installation Cost and Savings Data

$CONSAV_l$ is all procurement and construction costs avoided as a direct result of realignment of the losing installation l.

$ENVCOST_l$ is the total environment cleanup cost for the losing installation l.

$RECSAV_l$ is the recurring savings after completing actions at the losing installation l.

$RETIR_l$ is the yearly civilian early retirement cost at the losing installation l attributable to its realignment.

$SEVPAY_l$ is the cost for civilian reduction-in-force (RIF) attributable to the realignment at losing installation l.

$UNIQLCOST_l$ is the unique (non-standard) cost of actions required to realign losing installation l.

b. Gaining Installation Cost Data

$MILCON_{ct'q'tqg}$ is the cost of type c construction at the gaining installation g in the q-th half of year (year t dollars) when type c construction started in the q'-th half of year t'.

$TOTALMILCON_g$ is the total cost of construction at the gaining installation g.

$NEWHIRE_g$ is the cost of all new hires at the gaining installation g.

$UNIQGCOST_g$ is the unique (non-standard) cost of actions required to realign gaining installation g.

c. Transfer Cost Data from Losing to Gaining Installations

PCS_{lg} is the cost to move all civilians and the additional cost above normal rotation rates to move military personnel from the losing installation l to the gaining installation g. COBRA uses 100% of civilian strength and 54% of military strength to determine the BRAC-induced movement costs.

$FREIGHT_{lg}$ is the cost to ship all office and special equipment from the losing installation *l* to the gaining installation *g*.

d. *Unit Data*

$\underline{FIX}_{tqu}$, $\overline{FIX}_{tqu}$ together specify if unit u can move, cannot move, or must move in q, t (bounds on binary decision variable $unitmove_{tqu}$).

$MILSTRENGTH_u$ is the number of military personnel in unit *u*.

$CIVSTRENGTH_u$ is the number of civilian personnel in unit *u*.

$PERCENT_u$ is the percentage a unit contributes to the total personnel strength of units leaving its losing installation.

e. Additional Data

CY_{cg}, CQ_{cg} is the number of years and half years, respectively, required to complete type *c* construction at the gaining installation *g*.

TY_{ctqg} is the year when type *c* construction starts at the gaining installation *g*, which ends in the *q*-th half of year *t*, i.e., $TY_{ctqg} = t - CY_{cg} + 1$, if $CQ_{cg} = 0$ and $q = 2$, and $TY_{ctqg} = t - CY_{cg}$, otherwise.

TQ_{ctqg} is the half year when type *c* construction starts at the gaining installation *g*, which ends the *q*-th half of year *t*, i.e., $TQ_{ctqg} = 1$, if $CQ_{cg} = 0$ and $q = 2$, or $CQ_{cg} = 1$ and $q = 1$. $TQ_{ctqg} = 2$, if $CQ_{cg} = 0$ and $q = 1$, or $CQ_{cg} = 1$ and $q = 2$.

$DEVPEN_t$ is the penalty for exceeding the budget in year t.

DIS_t is the discount applied to a dollar in year t for the Net Present Value (NPV). ($DIS_t = 1/(1+d)^{t-0.5}$ where d is the COBRA discount rate.)

$OVERHEAD_{lt}$ is the program cost distributed over four years at the losing installation in constant dollars. $OVERHEAD_{lt} = 0 \quad \forall t \geq 5, \forall l$.

$PERLOW_{lt}$ is the minimum percent of the total environmental cleanup cost to allocate at a losing installation l in year t.

$PERHIGH_{lt}$ is the maximum percent of the total environmental cleanup cost to allocate at a losing installation l in year t.

REQ_g is the fraction of personnel and freight that can move onto the gaining installation without completing construction at the gaining installation g.

FE_l is the fraction of the total environmental cost that counts towards NPV calculations.

FED_l is the fraction of the total environmental cost that needs to be paid before installation can be closed.

$WEDGE_t$ is the total funds available for BRAC actions in year t (in year t dollars).

$CEIL_{tr}$ is the upper limit on military construction funds that can be managed in year t in Installation Management Agency (IMA) region r.

$EARLYPEN$ is the penalty factor incurred if movement to a gaining installation occurs before the completion of all construction.

4. Variables

a. Binary Decision Variables

$build_{ctqg}$ is one if type c construction at the gaining installation g begins during the q-th half of year t, and zero otherwise.

$unitmove_{tqu}$ one if unit u moves during the q-th half of year t, else zero.

$earlymove_{tqg}$ is one if a unit moves to gaining installation g in year t and half-year q prior to the completion of all military construction at g.

$done_{tql}$ is one if all actions at the losing installation l are complete during the q-th half and year t, and zero otherwise.

b. Continuous Decision Variables

$civrif_{tl}$ is the spending in year t (in year t dollars) for civilian receiving RIF notices at the losing installation l.

dev_t is the excess spending in year t, the amount exceeding $WEDGE_t$.

$envir_{tl}$ is the spending in year t (in year t dollars) for environmental cleanup costs at the losing installation l.

$hire_{tg}$ is the spending in year t (in year t dollars) for hiring at the gaining installation g.

$imaslack_{tr}$ is the amount in year t that MILCON spending in region r exceeds the region's annual limit, $CEIL_{tr}$.

$pper_{tql}$ is the fraction of realignment completed in the q-th half of year t for losing installation l.

$uniql_{tl}$ is the spending in year t (in year t dollars) for unique one-time costs at the losing installation l.

$uniqg_{tg}$ is the spending in year t (in year t dollars) for unique one-time costs at the gaining installation g.

5. Formulation

a. Objective Function

$$\max \sum_{t=7}^{20}\sum_{l} RECSAV_l * DIS_t - \sum_{t=1}^{3}\sum_{l} RETIR_l * DIS_t + \sum_{l} CONSAV_l * DIS_1$$

$$+\sum_{t'=1}^{6}\sum_{q'=1}^{2}\sum_{t=1}^{t'-1}\sum_{q=1}^{2}\sum_{l} RECSAV_l * DIS_t * \left(done_{t,q,l} + 3 * pper_{t,q,l}\right)/8$$

$$+\sum_{t'=1}^{6}\sum_{l} RECSAV_l * DIS_{t'} * \left(done_{t',1,l} + 3 * pper_{t',1,l}\right)/8 - \sum_{t=1}^{6}\sum_{g} DIS_t * hire_{tg}$$

$$-\sum_{t=1}^{6}\sum_{l} DIS_t * \left(uniql_{tl} + civrif_{tl}\right) - \sum_{t=1}^{6}\sum_{q=1}^{2}\sum_{t'=1}^{t}\sum_{q'=1}^{2}\sum_{g}\sum_{c} DIS_t * \left(MILCON_{ct'q'tqg} * build_{ct'q'g}\right)$$

$$-\sum_{t=1}^{6}\sum_{q=1}^{2}\sum_{l}\sum_{g \in G_l}\sum_{u \in U_{lg}} DIS_t * unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right) - \sum_{t=1}^{6}\sum_{g} DIS_t * uniqg_{tg}$$

$$-\sum_{t=1}^{6}\sum_{l}\sum_{g \in G_l}\sum_{u \in U_{lg}} DIS_t * unitmove_{tqu} * \left(PERCENT_u * FREIGHT_{lg}\right) - \sum_{t=1}^{20} DEVPEN_t * dev_t * DIS_t$$

$$-\sum_{t=1}^{4}\sum_{l} OVERHEAD_{tl} * DIS_t - \sum_{t=1}^{20}\sum_{l} envir_{tl} * FE_l * DIS_t$$

$$-\sum_{t=1}^{6}\sum_{q=1}^{2}\sum_{g} earlymove_{tqg} * EARLYPEN * TOTALMILCON_g - \sum_{t=1}^{6}\sum_{r} DIS_t * DEVPEN_t * imaslack_{tr}$$

b. Constraints

$$\sum_{l\,(if\ t \le 3)} RETIR_l + \sum_{l}\left(uniql_{tl} + civrif_{tl} + envir_{tl}\right) + \sum_{g} hire_{tg} + \sum_{g} uniqg_{tg}$$

$$+\sum_{q=1}^{2}\sum_{t'=1}^{t}\sum_{q'=1}^{2}\sum_{g}\sum_{c} MILCON_{ct'q'tqg} * build_{ct'q'g}$$

$$+\sum_{q=1}^{2}\sum_{l}\sum_{g \in G_l}\sum_{u \in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * FREIGHT_{lg}\right) \tag{1a}$$

$$+\sum_{q=1}^{2}\sum_{l}\sum_{g \in G_l}\sum_{u \in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right)$$

$$+\sum_{l} OVERHEAD_{tl} \le WEDGE_t + dev_t \quad \forall t \le 6$$

$$\sum_{l} envir_{tl} \le WEDGE_t + dev_t \quad \forall\ t \ge 7 \tag{1b}$$

$$
\begin{aligned}
&\sum_{t=1}^{t'-1}\sum_{q=1}^{2}\sum_{g\in G_l}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right) \\
&+\sum_{q=1}^{q'}\sum_{g\in G_l}\sum_{u\in U_{lg}} unitmove_{t'qu} * \left(PERCENT_u * PCS_{lg}\right) \\
&\geq \sum_{g\in G_l} PCS_{lg} * \left(\sum_{t=1}^{t'-1}\sum_{q=1}^{2} pper_{tql} + \sum_{q=1}^{q'} pper_{t'ql}\right) \quad \forall\ t' \leq 6,\ q', l
\end{aligned}
\tag{2a}
$$

$$
\sum_{t=1}^{6}\sum_{q=1}^{2} pper_{tql} = 1 \quad \forall l \tag{2b}
$$

$$
\frac{\sum_{t=1}^{t'}\sum_{q=1}^{2}\sum_{l\in L_g}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right)}{\sum_{l\in L_g} PCS_{lg}} \leq \frac{\sum_{t=1}^{t'} hire_{tg}}{NEWHIRE_g} \quad \forall\ t' \leq\ 6, g \tag{3a}
$$

$$
\begin{aligned}
&\frac{\sum_{t=1}^{t'}\sum_{q=1}^{2}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right)}{PCS_{lg}} \\
&\leq \frac{\sum_{t=1}^{t'}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * FREIGHT_{lg}\right)}{FREIGHT_{lg}} \quad \forall\ t' \leq\ 6,\ l,\ g \in\ G_l
\end{aligned}
\tag{3b}
$$

$$
\frac{\sum_{t=1}^{t'}\sum_{q=1}^{2}\sum_{l\in L_g}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right)}{\sum_{l\in L_g} PCS_{lg}} \leq \frac{\sum_{t=1}^{t'} uniqg_{tg}}{UNIQGCOST_g} \quad \forall\ t' \leq\ 6,\ g \tag{3c}
$$

$$\frac{1}{\sum_{l\in L_g} PCS_{lg}} * \left(\begin{array}{l} \sum_{t=1}^{t'-1}\sum_{q=1}^{2}\sum_{l\in L_g}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_{lg} * PCS_{lg} \right) \\ +\sum_{q=1}^{q'}\sum_{l\in L_g}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_{lg} * PCS_{lg} \right) \end{array} \right) \tag{3d}$$

$$\leq REQ_g + \left(1 - REQ_g\right) * \left(\sum_{c}\sum_{t=1}^{TY_{ct'q'g}-1}\sum_{q=1}^{2} build_{ctqg} + \sum_{c}\sum_{q=1}^{TQ_{ct'q'g}-1} build_{cTY_{ct'q'g}qg} \right)$$

$$+ \ earlymove_{t'q'g} \qquad \forall t' \leq 6,\ q',\ g$$

$$\frac{\sum_{t=1}^{t'-1} uniql_{tl} + \sum_{q=1}^{q'} 0.5 * uniql_{t',l}}{UNIQLCOST_l} \geq \sum_{t=1}^{t'-1}\sum_{q=1}^{2} done_{tql} + \sum_{q=1}^{q'} done_{t',q,l} \qquad \forall\ t' \leq 6, q', \ l \tag{4a}$$

$$\frac{\sum_{t=1}^{t'-1} envir_{tl} + \sum_{q=1}^{q'} 0.5 * envir_{t',l}}{FED_l * ENVCOST_l} \geq \sum_{t=1}^{t'-1}\sum_{q=1}^{2} done_{tql} + \sum_{q=1}^{q'} done_{t',q,l} \qquad \forall\ t' \leq 6, q', l \tag{4b}$$

$$\frac{1}{\sum_{g\in G_l} PCS_{lg}} \left(\begin{array}{l} \sum_{t=1}^{t'-1}\sum_{q=1}^{2}\sum_{g\in G_l}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg} \right) \\ +\sum_{q=1}^{q'}\sum_{g\in G_l}\sum_{u\in U_{lg}} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg} \right) \end{array} \right) \tag{4c}$$

$$\geq \sum_{t=1}^{t'-1}\sum_{q=1}^{2} done_{tql} + \sum_{q=1}^{q'} done_{t'ql} \qquad \forall\ \ t' \ \leq \ 6,\ q',\ l$$

$$done_{tql} \leq \sum_{t'=1}^{t-1}\sum_{q'=1}^{2} unitmove_{t'q'u} + \sum_{q'=1}^{q} unitmove_{tq'u} \ \ \forall t, q, l, u \in U_l \tag{4d}$$

$$\sum_{c}\sum_{t=1}^{TY_{ct'q'g}-1}\sum_{q=1}^{2} build_{ctqg} + \sum_{c}\sum_{q=1}^{TQ_{ct'q'g}-1} build_{cTY_{ct'q'g}qg} \geq \sum_{t=1}^{t'-1}\sum_{q=1}^{2} done_{tql} + \sum_{q=1}^{q'} done_{t'ql} \ \ \forall t' \leq 6, q', l, g \in G_l \tag{4e}$$

$$PERLOW_{tl} * ENVCOST_l \leq envir_{tl} \leq PERHIGH_{tl} * ENVCOST_l \quad \forall t', l \tag{5}$$

$$civrif_{tl} = \sum_{q=1}^{2} SEVPAY_l * done_{tql} \quad \forall\ t\ \le\ 6,\ l \tag{6}$$

$$\sum_{t=1}^{6}\sum_{q=1}^{2} done_{tql} = 1 \quad \forall\ l \tag{7}$$

$$\sum_{t=1}^{20} envir_{tl} = ENVCOST_l \quad \forall\ \ l \tag{8}$$

$$\sum_{t}\sum_{q} unitmove_{tqu} = 1 \quad \forall\ u \tag{9}$$

$$\sum_{t=1}^{6}\sum_{q=1}^{2} unitmove_{tqu} * \left(PERCENT_u * PCS_{lg}\right) \ge PCS_{lg} \quad \forall\ \ l, g \in G_l \tag{10}$$

$$\sum_{q=1}^{2}\sum_{t'=1}^{t}\sum_{q'=1}^{2}\sum_{g\in G_r}\sum_{c} MILCON_{ct'q'tqg} * build_{ct'q'g} \le CEIL_{tr} + imaslack_{tr} \ \ \forall t, r \tag{11}$$

$$\underline{FIX}_{tqu} \le unitmove_{tqu} \le \overline{FIX}_{tqu} \quad \forall t, q, u \tag{12}$$

$$\begin{aligned} &pper_{tql} \ge 0\,\forall\, t, q, l; \quad done_{tql} \in \{0,1\}\,\forall t, q, l; \quad build_{ctqg} \in \{0,1\}\,\forall c, t, q, g; \\ &unitmove_{tqu} \in \{0,1\}\,\forall t, q, u;\ \ civrif_{tl} \ge 0 \forall t, l;\ \ uniql_{tl} \ge 0 \forall t, l;\ \ uniqg_{tg} \ge 0 \forall t, g; \\ &envir_{tl} \ge 0 \forall t, l; \quad hire_{tg} \ge 0 \forall t, g; \quad dev_t \ge 0 \forall t; \quad bud_t \ge 0 \forall t. \end{aligned} \tag{13}$$

C. EXPLANATION OF THE MODEL

The objective function seeks to maximize the NPV of the total BRAC savings over a 20 year horizon. It sums the recurring savings in all years after closure through year 20 for all closing or realigning bases, as well as the one-time cost avoidances at each base. It subtracts all costs incurred in order to implement all closures and realignments. Finally, it penalizes any deviation above the annual implementation budget and unit movement before MILCON is completed.

Inequalities 1a and 1b limit all expenditures in a year to the annual budget, or measure any deviation. Note that Inequality 1a applies to only years 1 through 6, the

implementation horizon. The simpler Inequality 1b considers only environmental costs in years 7 through twenty, as all actions other than environmental clean up must already be complete.

Inequality 2a limits the percent of the realignment that is complete to the percent of personnel movement costs associated with unit moves. Inequality 2b requires all realignment actions to be completed by year six.

Inequalities 3a through 3d limit the moves of units to a gaining installation by ensuring the total fraction of the units moved does not exceed the fraction of the required expenditures for different categories of funds at the gaining installation. Inequality 3a links the moves to the hiring of new personnel. Inequality 3b links moves to the amount of equipment that has been shipped to the gaining installation from the losing installation. Inequality 3c links the moves to unique costs that must be paid at the gaining installation. Lastly, Inequality 3d requires that military construction at the gaining installation be complete before the majority of a unit moves, or records an early move (which is penalized) otherwise.

Inequalities 4a through 4e require that certain activities be completed before an installation losing activity can be declared finished and can start contributing recurring savings. Inequality 4a requires payment of all the unique costs associated with the installation. Inequality 4b ensures payment of the minimum required percentage of total environmental costs. Inequality 4c demands payment of the total bill to move all personnel, while Inequality 4d simply requires that all units moving from an installation have moved before the action considered complete. Inequality 4e ensures military construction at an installation gaining activity from a losing installation has been completed before the losing action is declared complete.

Inequality 5 establishes minimum and maximum environmental expenditures for every budget year by installation.

Equation 6 pays the total civilian personnel separation actions cost.

Equation 7 closes or realigns all installations losing activity by the end of the six year implementation period, while Equation 8 pays the entire environmental cleanup cost by the end of the twenty year horizon.

Equation 9 moves every unit exactly once.

Inequality 10 ensures the total bill for moving personnel is paid.

Inequality 11 limits the total military construction in a given year and region.

Inequality 12 ensures units move only when available. For a given period, we set $\underline{FIX}_{tqu} = \overline{FIX}_{tqu} = 0$ if a unit is unavailable to move, $\underline{FIX}_{tqu} = \overline{FIX}_{tqu} = 1$ to force a move, or $\underline{FIX}_{tqu} = 0$ and $\overline{FIX}_{tqu} = 1$ otherwise.

The statements labeled Equation 13 require all decision variables in the model be nonnegative or binary.

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IV. RESULTS

A. MODEL IMPLEMENTATION

1. Assumptions

Units are considered unavailable to move during 18-month periods comprising training, deployment, and recovery. The training and recovery periods, spent primarily at the unit's home installation, are included in the 18-month window from the end of one deployment to the beginning of the next. This leaves a unit available for only 12 months in a 30-month period.

Modularity requirements and implementing LCM each render a unit unavailable to move for a six-month period.

We consider RC units available to move at all times; reserve units would primarily relocate to new facilities within the same local area. BRACAS could easily accommodate any specified unavailability.

COBRA cost estimates are dated but accurate. COBRA uses a past snapshot of installation status for cost estimates. The BRAC Division of the Assistant Chief of Staff for Installation Management is gathering installation data to guide implementation; BRACAS can be updated as new data are available.

2. Data

COBRA data are the DoD standard for all internal comparative analyses for BRAC. COBRA accepts data from a variety of information sources and produces a several reports for every proposed stationing action. BRACAS requires the COBRA cost estimates by categories and the expected duration of all MILCON projects for every stationing action. COBRA reports these figures for every installation, whether gaining or losing an activity.

The Total Army Basing Study (TABS) office provides a list of units or activities moving from each losing installation, what installation they are moving to, and the assigned military and civilian personnel strength of the unit.

We construct the data regarding unit availability from several sources. Army publications provide the schedules for modularity and LCM. We use open sources to

estimate when major units deploy. We assume non-availability windows of 18 months, to allow for one-year deployments with preparation and recovery, followed by a 12-month availability period. We base this on a respite of 18 months between deployments; units use six months for deployment preparation and recovery. This accurately reflects today's thirty month cycle, though the Army Force Generation Model aims to ultimately achieve a two year time at home station between deployments.

The data we use come from a candidate set of recommendations TABS considered during its BRAC analysis. The data closely match the final recommendations released by DoD. While we believe this represents the actual BRAC implementation challenge well in terms of overall costs, units and activities moving, and so on, we cannot guarantee the conclusions and insights below hold for the actual BRAC 2005 data.

3. Software

We implement BRACAS using the Generalized Algebraic Modeling System (GAMS) Integrated Development Environment. GAMS [2004] is a tool for encoding mathematical programming formulations such as BRACAS, generating an instance of the problem, interacting with separate software packages that actually solve the problem, and receiving and displaying output reports from the solver software. BRACAS as described above is a mixed integer linear program. We use the CPLEX 9.0 solver [GAMS-CPLEX, 2004].

4. Computational Results

Our BRACAS instance represents moving or realigning over 2,500 units or activities from over 600 installations (mostly small installations such as reserve centers), while initiating MILCON projects at over 170 different locations at a cost of about $11 billion over six years. When GAMS generates a model for this data and the formulation above, the result is about 130,000 equations and 165,000 variables, of which 40,000 are binary.

Model generation averages about 10 minutes. This is a significant increase over the previous version of BRACAS, where the model generates in about 20 seconds. Solution times vary, but are most frequently around 10 minutes, using an optimality gap of 0.01%. This is also a significant increase, as the previous BRACAS solves the same instances in about one minute.

While slower solve times are not desirable, they are still well within reasonable time limits. The inclusion of additional sets, indices, data tables, and binary decision variables accounts for this increased computational cost. For the reasons explained previously, we feel this is a minor inconvenience and a worthwhile trade-off to improve the modeling of this problem. Table 2 and Figure 1 compare the models.

	PREVIOUS	CURRENT
BLOCKS OF EQUATIONS	31	30
BLOCKS OF VARIABLES	15	14
SINGLE EQUATIONS	25356	129364
SINGLE VARIABLES	55393	163377
DISCRETE VARIABLES	9540	40284
NON ZERO ELEMENTS	414509	2732486
GENERATION TIME	19.953	497.25
EXECUTION TIME	65.531	520.954

Table 2. Model Statistics Comparison For BRACAS Versions

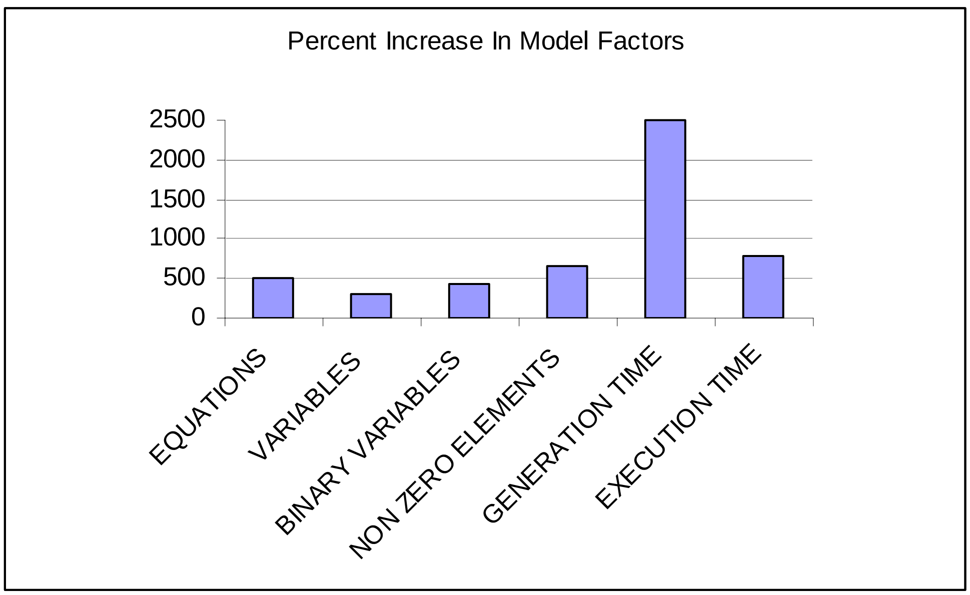

Figure 1. Percent Increase in Model Factors

B. COMPARISON OF SOLUTIONS BETWEEN BRACAS VERSIONS

The solutions from the most recent version of BRACAS developed prior to this thesis and the formulation described above closely coincide: we see only a 1.5% difference in the 20 year NPV. The modified version of BRACAS incorporates unit data and shares aggregated costs according to strength. This explicit handling of fair-share costs produces a more accurate calculation, but does not change the scale of the problem

appreciably. We hope this encourages those with confidence in the previous version results to consider the new version favorably.

C. EXPLORATORY ANALYSIS

1. Anticipated Questions in Planning BRAC Implementation

The list below contains some key questions we anticipate planners and decision makers may ask during BRAC implementation:

Q1. Does BRAC force a change in other plans and schedules – deployments, transformation, or life cycle manning?

Q2. What is the maximum savings with an unlimited implementation budget?

Q3. What additional costs or savings result from dictating a particular movement schedule?

Q4. What is the effect of moving units before all construction is complete at the gaining installation?

Q5. What is the effect of limiting in-progress MILCON to a specific annual limit per year in every region?

Q6. What budget is required for the fastest possible completion of all BRAC actions?

Q7. How much can we delay implementation and still complete BRAC on time?

2. Modifications for Exploratory Analysis

We modify aspects of the basic model to address the questions above. We describe the modeling changes here and subsequently present results.

Q1. Does BRAC force a change in other plans and schedules – deployments, transformation, or life cycle manning?

We represent other plans and schedules by manipulating $\overline{FIX}_{tqu}$ and $\underline{FIX}_{tqu}$. We overlay the schedules for deployments, transformation, and LCM on a single timeline. We represent committed time as a 1 on a unit's timeline. Our implementation of

Equation 12 ensures no unit moves during these unavailable times. Any feasible solution means it is possible to implement BRAC without additional schedule changes.

Q2. What is the maximum savings with an unlimited implementation budget?

To determine the maximum possible savings, we remove all budget limits. This relaxation determines the theoretical maximum savings.

Q3. What additional costs or savings result from dictating a particular movement schedule?

We measure the impact of a specified unit movement schedule by adjusting the $\overline{FIX}_{tqu}$ and $\underline{FIX}_{tqu}$ bounds to the appropriate values.

Q4. What is the effect of moving units before all construction is complete at the gaining installation?

There must be facilities available at the gaining installation to receive a unit. However, this requirement does not mean that all BRAC-related MILCON must be complete prior to a unit move. The Army has the option of using existing facilities if available or temporary facilities otherwise. We introduce an additional binary variable into Equation 3d. This allows the unit to move either before or after MILCON is complete. To deter early moves we include a penalty in the objective function. This penalty represents the additional costs of an early move. We can adjust this penalty to reflect the costs of a particular scenario.

We consider this early move option for several reasons. First, the Army is using temporary facilities for newly created units as transformation proceeds while awaiting final BRAC decisions. This means there is a precedent and it is worth considering [Loring, 2004]. Second, it provides additional flexibility while planning implementation. Other requirements like the deployment rotation may make it advantageous to move a unit before all MILCON is complete. This modification makes exploration of these options readily available, even though such options and costs were not part of the original BRAC analysis. Finally, we need this modification to answer questions regarding specified unit movement timelines that would otherwise violate the requirement to wait for MILCON.

Q5. What is the effect of limiting in-progress MILCON to a specific annual limit per year in every region?

Planners seek to minimize the difficulty in managing implementation for all Army agencies. IMA has four regions within CONUS, each responsible for overseeing MILCON projects on its installations. We place annual limits by region on MILCON expenditures. This entails the addition of several features to the model. First, we add the set of affected IMA regions, and we index all gaining installations by region. We then implement Equation 11. We introduce an elastic variable to allow for a feasible solution if the desired limits prove too restrictive. Finally, we modify the objective function to penalize exceeding the limits.

Q6 and Q7. What budget is required for the fastest possible completion of all BRAC actions? How much can we delay implementation and still complete BRAC on time?

In order to determine the fastest and slowest possible implementation timelines and their associated budgets, we manipulate the cost of money. By manipulating the discount rate, we make it extremely advantageous to spend money sooner. This generates the fastest feasible movement schedule. We then record this schedule, restore the discount rate to the proper level, and resolve. This solves for the other variables, and produces the accompanying budget that enables the fastest possible schedule. A similar approach makes spending later advantageous. This shows us the minimum required expenditures to complete all actions within the six-year implementation period.

3. Changes to Other Plans and Schedules

There is no need to change operational or transformation plans in order to accomplish BRAC on time. We include these schedules for major units, including the 1st Infantry Division and 1st Armored Division from Germany, 2nd Infantry Division from Korea, and the 7th Special Forces Group (Airborne), currently at Fort Bragg. BRACAS produces a supporting movement schedule and budget. The impact on total savings is negligible (less than $4 million) when compared to an otherwise identical model where units can move at any time.

It is important to note we limited only a few major units in their availability to move. If all RC units are similarly restricted, the impact on savings could be more dramatic.

We must emphasize here the unit availability data: Rotation schedules, force levels requirements, and implementation timelines for both transformation and life-cycle manning are difficult if not impossible to forecast accurately a full six years. Some of the required data may also be classified (a classified version could be used). This essential input data must be carefully examined and validated before drawing conclusions and approving implementation plans.

4. Maximum Savings Given Unlimited Budgets

We find the Army could save an additional $900 million with an unlimited budget, compared to the proposed budget (see Figure 2 and Table 3). The budget required for optimal savings, also shown in Table 3, is likely infeasible due to other considerations. Figure 2 compares optimal execution by fiscal year (FY) for planned and unconstrained budgets. From this we infer an increase in the year one budget may incur additional net savings. The potential $900 million reward warrants a detailed exploration of possible budget levels.

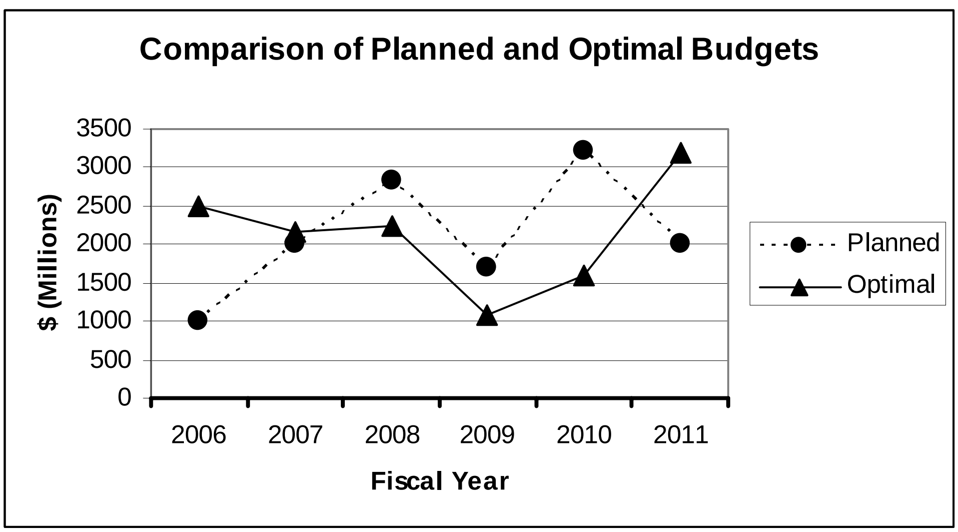

Figure 2. Comparison of Planned and Optimal Budgets.

Fiscal Year	Limit	Planned	Unlimited	Difference
2006	1000	1000.00	2484.41	1484.41
2007	2000	2000.00	2163.49	163.46
2008	3000	2828.46	2244.1	-584.36
2009	none	1697.89	1084.5	-613.38
2010	none	3212.40	1597.25	-1615.15
2011	2000	2000.00	3178.59	1178.59

Table 3. Optimal Execution of Planned and Unlimited Budgets ($ Millions).

5. Additional Costs or Savings from Dictating a Movement Schedule

We schedule the move of 1st Infantry and 1st Armored Divisions, and their associated support units, to 2006 and 2008, respectively. If we assume no additional costs for these early moves, we find an additional savings of nearly $4 billion in total NPV. However, if we represent the estimated cost of temporary facilities as 25% of the total MILCON bill at the gaining installations, these moves lose over $1 billion in NPV. We see two possible causes for this: the direct additional MILCON cost, and the reallocation of funds from other BRAC actions in early years, delaying other savings. Clearly our assumption that there would be no additional costs is unrealistic. However, if these costs amount to less than $4 billion total, an early move will be beneficial. We conclude this early return of forces from overseas is potentially profitable, but very sensitive to additional costs.

6. Effect of Moving Units before Construction is Complete

Referring to the proposed move of units from Germany in 2006 and 2008 described above, we see that an additional facility cost as low as 25% of the planned total can have a negative impact on overall savings. In general, early moves mean significant additional costs, and should not be the general rule. However, with accurate cost estimates, BRACAS can assist in determining which early moves are most valuable.

7. Requirements for Fastest Possible Completion of All Actions

Tables 4 and 5 show the total and MILCON budgets required to complete all actions at the earliest possible date. Figure 3 depicts the number of units moving by each FY. There appears to be little benefit from undue haste in implementation.

8. Delayed Implementation

Tables 4 and 5 show the total and MILCON budgets that delay BRAC implementation as much as possible. Figure 3 depicts the unit moves by FY. Note that nearly every unit moves in the last year, an undesirable outcome due to possible readiness implications. Only minimum required MILCON budgets are paid prior to the last year, when about half of the total implementation dollars are spent. The sole advantage of this approach seems to be the ability to maintain a low implementation budget for several years. The penalty is a steep bill in the final year of implementation.

Fiscal Year	Planned	Fastest	Slowest
2006	1000.00	5210.18	887.62
2007	2000.00	3240.60	1204.36
2008	2828.46	2334.26	1306.61
2009	1697.89	778.54	1270.25
2010	3212.40	735.88	2295.89
2011	2000.00	428.05	5761.32

Table 4. Total Budget Comparison by Implementation Plan ($ Millions).

Fiscal Year	Planned	Fastest	Slowest
2006	412.36	1945.47	373.59
2007	1026.21	2604.71	712.63
2008	1465.91	1187.18	831.61
2009	1512.76	707.41	1232.62
2010	1683.41	700.96	2248.95
2011	1045.06	0	1746.32

Table 5. MILCON Budget Comparison by Implementation Plan ($ Millions).

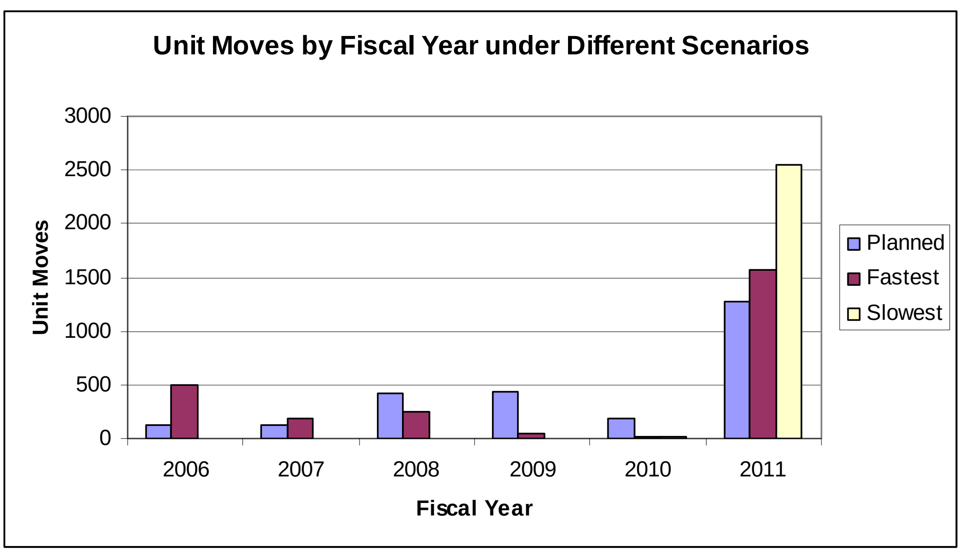

Figure 3. Unit Moves by Fiscal Year under Different Scenarios.

9. Regional MILCON Limits

We first sought to limit the regional annual in-progress MILCON to $300 million. This was infeasible, primarily due to the large MILCON costs associated with Fort Bliss, Texas. This necessitated the introduction of an elastic variable. When we penalize this elastic variable, we get the optimal limits, by region by year. The highest annual limit approached $600 million. Figure 4 shows the amount the cap is exceeded by region by FY. Based on these results, we tested a $500 million limit, and found this was feasible and had minimal impact on total savings.

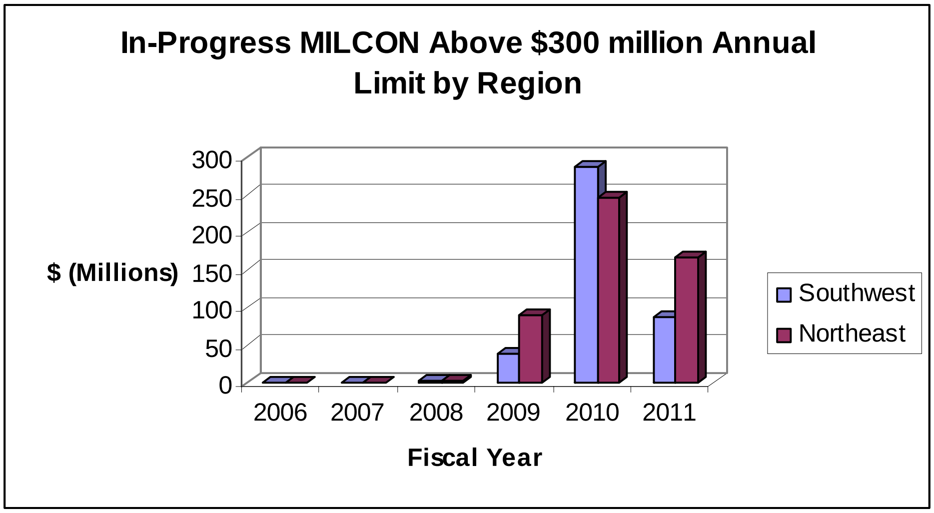

Figure 4. Excess In-Progress MILCON by Region and Fiscal Year.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS FOR BRAC IMPLEMENTATION

1. Synchronization of BRAC, Transformation, and War

The Army is transforming and at war. Our results show that BRAC implementation can be executed in this environment without major changes in budgets or unit schedules for deployment or transformation, while still yielding the anticipated savings.

2. Additional Savings Possible

The annual budget limits used for this analysis – $1 billion, $2 billion, and $3 billion in FY 2006, 2007 and 2008, respectively – may cost the Army up to $900 million in unrealized savings. Further exploration of a variety of acceptable budget scenarios will likely reveal opportunities to achieve some portion of this potential savings.

3. Impact of Early Movement of Overseas Forces

Moving the 1st Infantry and 1st Armored Divisions from Germany to the United States in 2006 and 2008 as discussed is feasible, but this time is too short to complete all MILCON at the gaining installations. Additional savings result if the cost of temporary facilities, renovations, or accelerated MILCON is under $4 billion. However, if these additional costs reach 25% of the planned MILCON cost and yearly budgets are limited, these early moves lose $1 billion in NPV savings relative to waiting for MILCON completion. Accurate cost estimates are essential to understand the true value of these actions. Minimizing additional costs to enable these moves is essential to reap any additional savings.

4. Flexibility in BRAC Implementation Schedule

After considering the fastest and slowest possible implementation schedules we conclude there is significant flexibility in the timing of BRAC actions. However, significant flexibility requires major shifts in budget levels, which may not be feasible. We speculate the large number of RC actions – relatively inexpensive actions with no unit timing restrictions – allow for many nearly optimal solutions even with a restricted budget without major schedule changes in deployments or transformation.

5. Regional MILCON Limits

A proposed annual regional in-progress MILCON limit of $300 million is infeasible. Both the Northeast and Southwest regions of IMA exceed this limit in most implementation years. A cap of $500 million is feasible for all regions in all years.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Joint Implementation

All services and DoD could use BRACAS, though other services may wish to consider additional constraints. COBRA data is available, as are the data regarding unit strength and availability, though preparing and consolidating all data is a significant task. Other services may benefit from using BRACAS in detailed implementation planning to synchronize BRAC with their wartime requirements.

2. Integrate All Basing Decisions

The model can also incorporate the decisions regarding the basing of forces currently overseas. While overseas basing decisions are distinct from BRAC, the model makes no such distinction. BRACAS can readily accommodate a simultaneous exploration of the impact on budgets, transformation, or movement schedules of basing decisions, regardless of source.

3. Refine Time Periods

Currently the model allows a unit to do only one task in any six month period. This may be deployment, transformation, or moving to another installation. By refining the time periods under consideration from half-years to quarters, it may be possible to find alternate implementation schedules. These schedules may also generate slightly higher savings. Implementing this change would require recoding of the cost data preprocessing within the model, and refinement of unit availability data. Significant changes in annual budgets and total savings are unlikely, but a wider variety of possible unit movement schedules may be worth pursuing if there is dissatisfaction with the resulting schedules produced using half-years.

4. Refine Projections for Unit Availability

Projecting unit availability with accuracy several years into the future is a daunting challenge. Nevertheless, this data is fundamental to the reliability of the results. There are techniques available to consider the persistence of a solution under changing

conditions [Brown, Dell, and Wood 1997]. We recommend that most accurate data on expected unit availability be used as a baseline. If provided alternate data for likely scenarios (increased or decreased wartime requirements, increased modularity requirements, etc.), solutions can be compared to determine whether they are effective in all scenarios. Comparing model results under a variety of possibilities can produce an implementation plan that will be good under this uncertainty.

5. Retain a Strategic Reserve During Implementation

With forces heavily committed to combat operations, and some units unavailable due to transformation, LCM, or unit moves, the Army must be cautious about maintaining adequate forces to deal with any contingency that may arise. An analysis of combat unit availability, incorporating deployments, transformation and the BRAC movement plan may show too few units in reserve at times. BRACAS can be modified to limit total moves by time period, producing an alternate movement schedule that maintains a strategic reserve.

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